Perry DEHC Test Platform

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Perry DEHC Test Platform

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History

Using simulators to test plant hardware has always been an interesting subject. FirstEnergy Nuclear Operating Company (FENOC) Davis Besse plant has long been doing this:

- Foxboro I/A applied to ICS – Babcock & Wilcox Owners Group (early 1990s)
- Unit Load Demand system upgrade to ICS (2010 – 2012)
- GE Mark Vle DEHC Turbine Control System (2013)
And this year, FENOC Perry plant is doing the GE Mark VIe Turbine Control System in the same manner as Davis Besse. Testing is under way.

Here is a photo of the installed DEHC Test Platform at Perry.
By interfacing new plant hardware to training simulator models, customers can test the new hardware performance prior to plant installation. The Test Platform performs the function of interfacing plant control systems to a training simulator. The existing model for the original plant system is replaced with the new plant equipment, often called “hardware in the loop”. The interface begins with CAN IO, similar to interfacing the control boards of the Main Simulator.

To provide realistic field connections to the new plant equipment requires custom electronic design to duplicate the specifications of the field signals in the plant. The CAN IO drives the new signal emulators with simulator model process values which in turn interface to the new plant hardware. This presentation introduces a few of the more challenging signals involved with DEHC.
Benefits

- Verify appropriate performance of new plant systems before plant installation
- Prepare plant personnel for required field connections – shortens outage schedule
- Verify installation schedules
- Correction of performance discrepancies prior to plant installation
- Training of plant personnel on operation of the new equipment
- When the project is complete, use the test platform with a second copy of the plant system as a permanent training facility for plant personnel
- All simulator interfaces are defined ahead of simulation model development, which will proceed after plant installation.
Overview

The test platform is two 6’ racks. The front and back contain the equipment to interface the DEHC to the simulator computer. This is the front.

The front left half contains all digital connections. The right half contains standard analog connections, mostly current loops and some analog voltages.
This is the back. All the signals involve custom designs to simulate the signal characteristics the DEHC expects to acquire in the plant. This presentation focuses on these signals.

The left half contains the 3 Current Transformer (CT) signals, power supplies for the whole test bed, and the 6 magnetic speed pickup signals.

The right half contains the LVDT signal simulators. There are provisions for 72 valve positions.
CTs

Three Current Transformer signals are simulated, representing the 3 Main Generator phase currents.

CTs are toroid coils placed around each phase of the Main Generator. The induced current can be as high as 5 Amperes RMS, and is something over 4 Amperes RMS at normal 100% power.

This photo shows the constant current sources across the top, the phase signals on the second rail, and the power supplies at the bottom.
The simulation starts with the rightmost module, a 60 Hz 3 phase waveform generator. Each phase is 120 degrees out from the other two. Each phase signal inputs to a custom VCA. The amplitude of each phase is attenuated according to simulated CT current measured on the Main Generator. The simulated current comes from the simulator via a CAN AO module. The modulated phase current signals are inputs to the Constant Current Source amplifiers.
This is a close-up photo of the Voltage Controlled Amplifier (VCA) PCB.

Power is supplied via the middle terminal strip.

The left terminal strip is where the input and output signals connect, including signal input, the control signal, and the attenuated output. The fourth screw is ground.

This high precision VCA supplies a maximum of 140 db of attenuation.
The constant current sources are capable of over 5 A rms, up to 10 A zero-to-peak. Their outputs are wired via knife switches to the DEHC CT sensors using 14 AWG wire. The DEHC CT sensors present a load of 0.03 ohm to the constant current sources, which is almost a dead short. This operational amplifier design produces a very clean high current waveform and dissipates very low heat.

The power supplies are positive and negative 12 VDC, each capable of 27 A. These supplies are dedicated to the CT simulators.
Six magnetic pick-up speed sensor signals are simulated. The speed sensors create a sine wave by magnetically sensing the passing teeth of a gear driven by the turbine shaft. There are 160 teeth on the gear, giving:

\[ F = \text{RPM} \times \frac{160}{60} \text{ sec/min} \]

Frequency is calculated by the blue Raspberry Pi computers, one for each turbine speed signal from the simulator computer via CAN AO.
The Pi controls a digital sine wave generator by providing F as a 32-bit number to its input. This produces control down to 0.029 Hz per step over the entire range. Lastly, the Pi calculates an attenuation signal to reduce the amplitude of the sine wave starting at 800 RPM (2133.33 Hz) down to flat line. This simulates the loss of signal due to less magnetic pick-up with lower speeds.
The outputs of the Pi go to custom VCA boards. There, the speed pick-up signal is attenuated as the turbine speed falls below 800 RPM. The output of the VCA goes to a knife switch to connect to the DEHC.

Now we will peek at the design process by examining the Pi plate.
Speed Pick-Ups (continued)

This is a photo of the plate designed for the Pi. It is shown mounted on the Pi.

It contains a digital IO expander IC controlling a Direct Digital Synthesis (DDS) signal generator, a 16-bit ADC to input turbine speed in RPM, and a 12-bit DAC to supply an attenuation signal for amplitude control.
This is the schematic of the speed plate for the Pi. There are three ICs communicating to the Pi on an I2C (Inter-Integrated Circuit) bus, a two-wire high speed bus. The bus originates from the Pi GPIO connector. The three peripherals are:

- IO expander, adding 16 digital IO
- ADC (Analog to Digital Converter)
- DAC (Digital to Analog Converter)
The IO expander controls the DDS which outputs the speed pick-up signal. The ADC receives Turbine Speed from the simulator computer via CAN AO. The DAC outputs the attenuation signal to simulate speed signal decrease due to slowing down below 800 RPM.
Once the parts are placed on the schematic, they automatically appear on the PCB layout drawing. The parts are positioned as desired. Auto routing is used to draw the connections. Routing is manually corrected. Silkscreen markings are manually placed on the board.
Speed Pick-Ups (continued)

As the design approaches completion, a 3D picture of the finished product can be observed. This image can be rotated, zoomed, and panned to fully examine the front and back of the PCB. Errors may be corrected on the PCB layout screen previous slide.
As parts are added to the schematic, they are automatically added to the Bill of Materials (BOM). If Digi-Key parts are specified, the prices can be automatically obtained, giving the user a total price of the PCB including parts.

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Total: $159.60
Once the PCB design is complete, the drawing package is uploaded to the PCB manufacturer for fabrication. For a small order like this, fabrication is completed in two days. These boards were then delivered to the PCB assembler, a partner of the fabricator. It is the customer’s option whether to supply the parts or let the assembler order them. CORYS prefers to order the parts and ship them to the PCB assembler. This provides more control over the project by guarding against backordered or obsolete parts, which can lead to redesigning the PCB and/or the schematic.
Pictured are half the 72 Linear Variable Differential Transformers (LVDTs) in this project. Two LVDTs are used for each steam throttle valve and bypass valve in Perry plant. An LVDT sensor is a tube transformer with a primary winding in the middle and secondary windings on both ends. A magnetically sensitive rod shaped core travels inside the tube mechanically connected to the valve. The DEHC provides an excitation signal to the primary winding (7V RMS sine wave at 3.2 KHz). The output of the secondary windings feeds back to the DEHC.
LVDTs (continued)

The secondary amplitude is linearly proportional to valve position. The top rail contains the CAN AO modules which provide valve position to the LVDT PCBs. The second rail contains the knife switches connecting the feedback signals to the DEHC. The third rail contains 18 LVDT PCBs, simulating 36 LVDT feed back signals. The fourth rail contains knife switches connecting the excitation signals from the DEHC (3 V RMS at 3.2 KHz) to the LVDT PCBs.
The close-up photo is the LVDT PCB. It contains circuitry for two LVDT simulated feedback signals. The left and right terminal strips are for each circuit. They connect incoming excitation, valve position input from the simulator computer, and modulated feedback to the DEHC (amplitude modulated excitation proportional to valve position).
Valve position drives the gate of a JFET directly, used as a voltage controlled resistor. The linear range of the JFET is used to amplitude modulate the excitation signal to produce the feedback signal to the DEHC.
CORYS has believed in the value of doing this type of project using training simulators since Ryan Nuclear’s formative years in the early 1990’s. The latest of these projects is the Perry DEHC Test Platform, which interfaces the GE Mark VI DEHC to the Perry training simulator. Today, the test bed is installed in the Perry training center. Two complete DEHC systems are installed in the same room as the test bed. The one designated as a permanent training facility is presently wired to the test bed. The plant system engineers are performing tests on the system, the same tests that are run for a plant installation. These include calibration, test, rolling the Main Turbine, bringing the plant to 100% power, and performing plant trips.
Later, when the system is scheduled to be installed in the plant, the wires to the test bed will be lifted from the DEHC cabinet terminals and moved with the test bed to the designated plant DEHC system, located across the room from the training unit. The same battery of tests will be performed on the designated plant DEHC prior to installation in the plant. When tests are completed, the plant DEHC will be moved to the plant and installed. The test bed will remain in the training building, rewired to the designated training DEHC, which will become a permanent training facility for process and control technicians and engineers.
Close (continued)

Davis Besse, the first FENOC plant to do this in 2013, went through a similar process. Testing was done first on the plant system, inside the power plant where the DEHC was installed. When tests were completed, the test bed was moved to the Davis Besse training building where the second DEHC system was installed and wired to the test bed. It is now a permanent training facility used for process and control technician and engineer training.

CORYS hopes this presentation inspires others to pursue projects of this kind. We look forward to serving the industry’s needs.
Close (continued)
Thanks / Credits

Yves Lacombe – Principal Engineer. Set up IO database from GE Mark VIe Tools and Perry Plant configuration data.
Romeo Relampagos – Hardware Technician. Made the wiring look “wireless”.
Jody Ryan – CEO. Had the vision to pursue this use of training simulators.
Laurent Leo – THOR engineer. Photographed the Test Platform

THANK YOU ALL FOR YOUR KIND ATTENTION

Glad to answer your questions now.